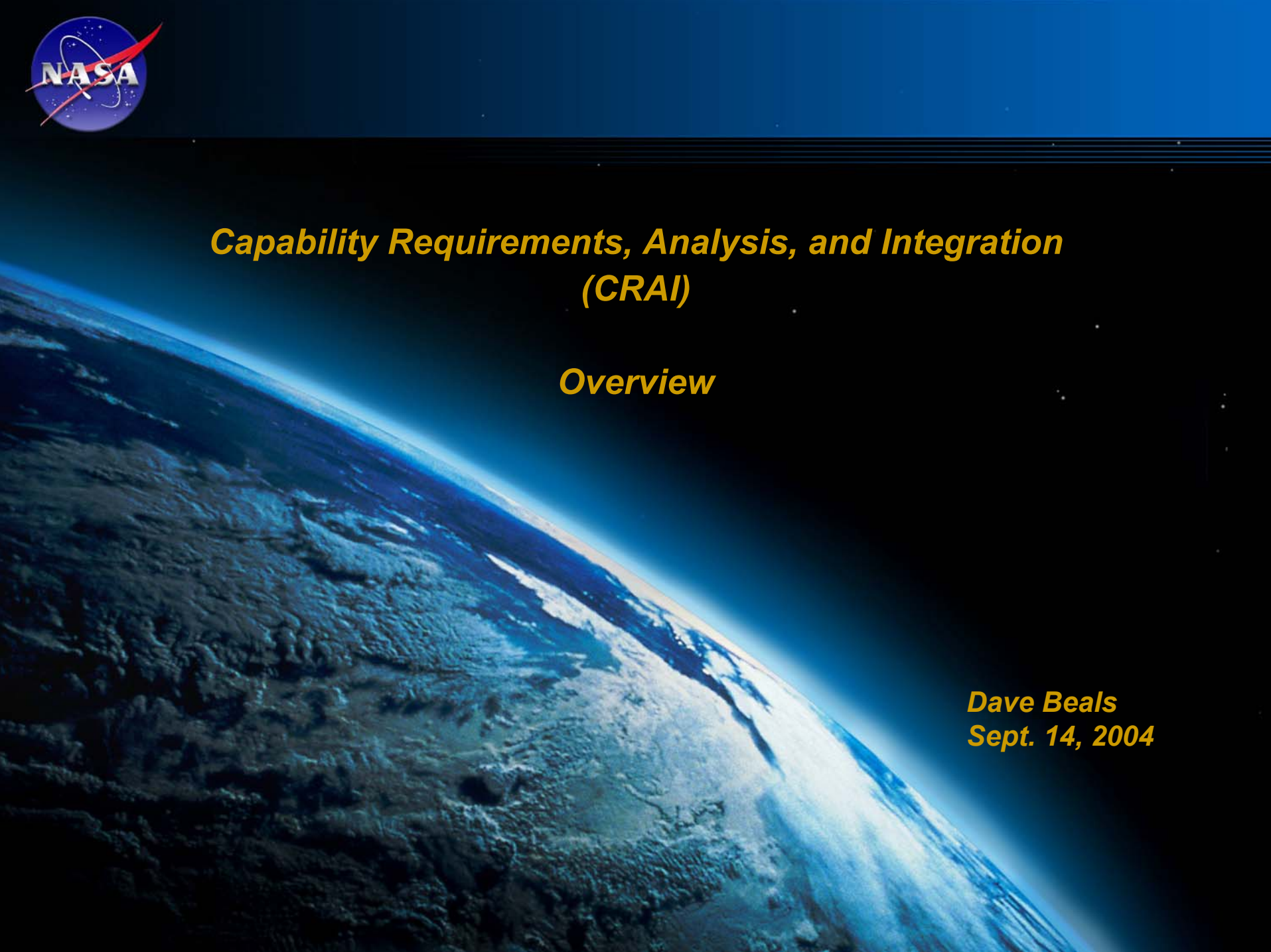


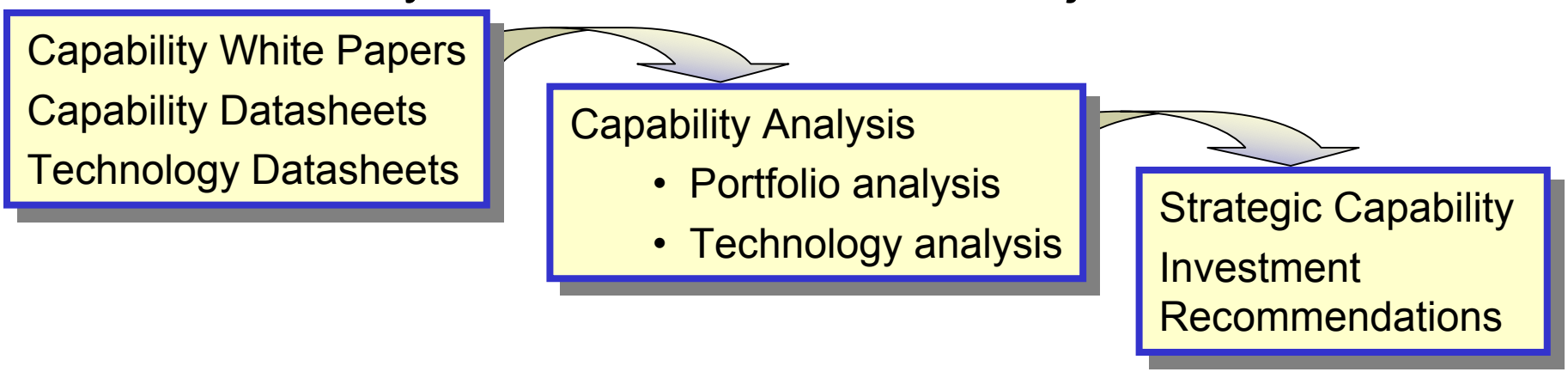
Capability Requirements, Analysis, and Integration (CRAI)

Overview

Dave Beals
Sept. 14, 2004

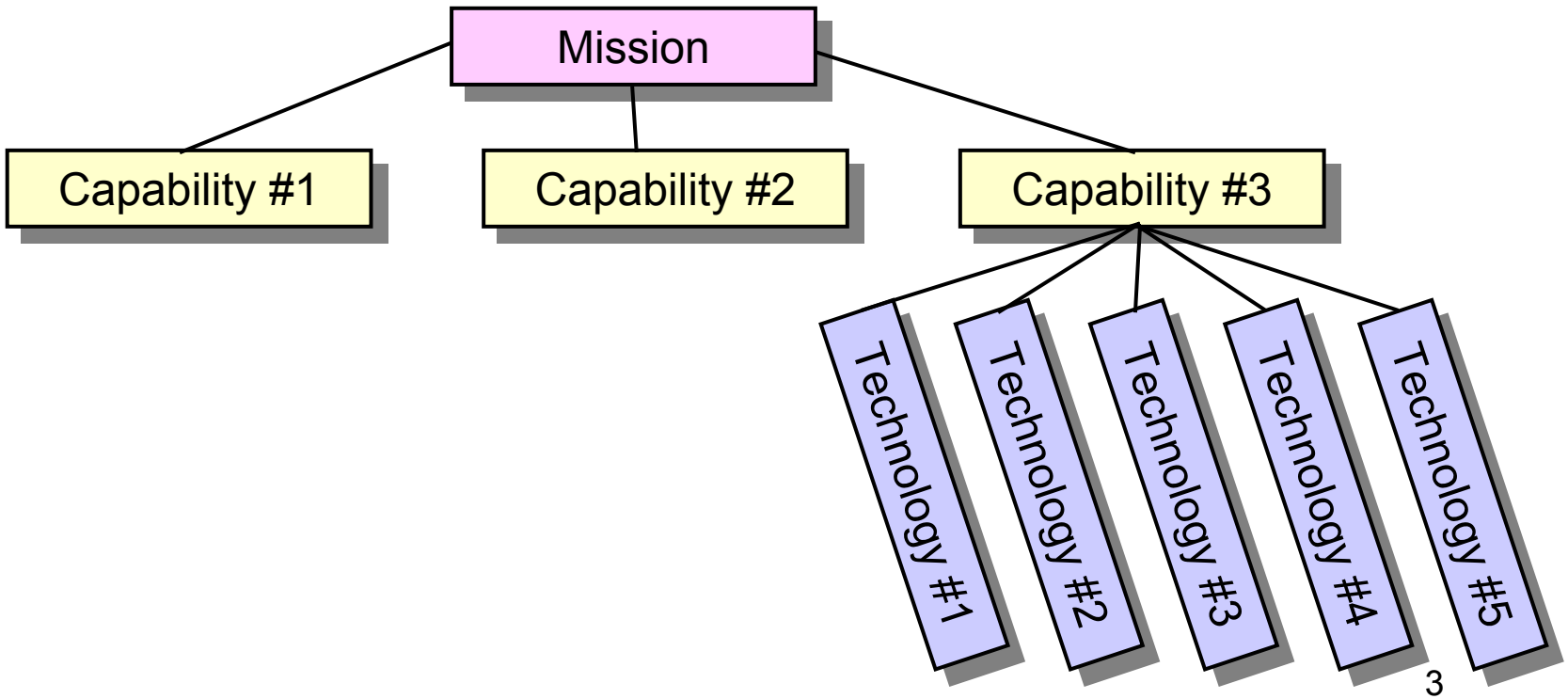
CRAI Concept

- Identification, assessment, prioritization, and strategic investment recommendations of capabilities needed to realize the NASA mission.
- Integrates capabilities across the Agency Enterprises, looking for connections and leverage opportunities.
- OneNASA analysis approach, products, and teams. Purposefully modeling OneNASA behavior.
- A structured, open, strategic analysis process with traceability to NASA missions and objectives



Capabilities

- Capabilities:
  - The ability to do <something>
  - Broad term used to define functional ability to accomplish or satisfy a mission
  - Capabilities are enabled by Technologies
  - Best viewed as a hierarchical structure



The Contribution of CRAI

- The Product:
  - Development of the “capabilities” concept
  - Database of capabilities and underlying technologies linked to exploration needs
    - High confidence minimum set of capabilities that must be acquired to do the exploration mission
      - What their current state is
      - What it will take to get to TRL = 6
  - Roadmaps for acquisition of capabilities
    - How to acquire them
  - The data package needed for investment decisions
    - How to prioritize among them

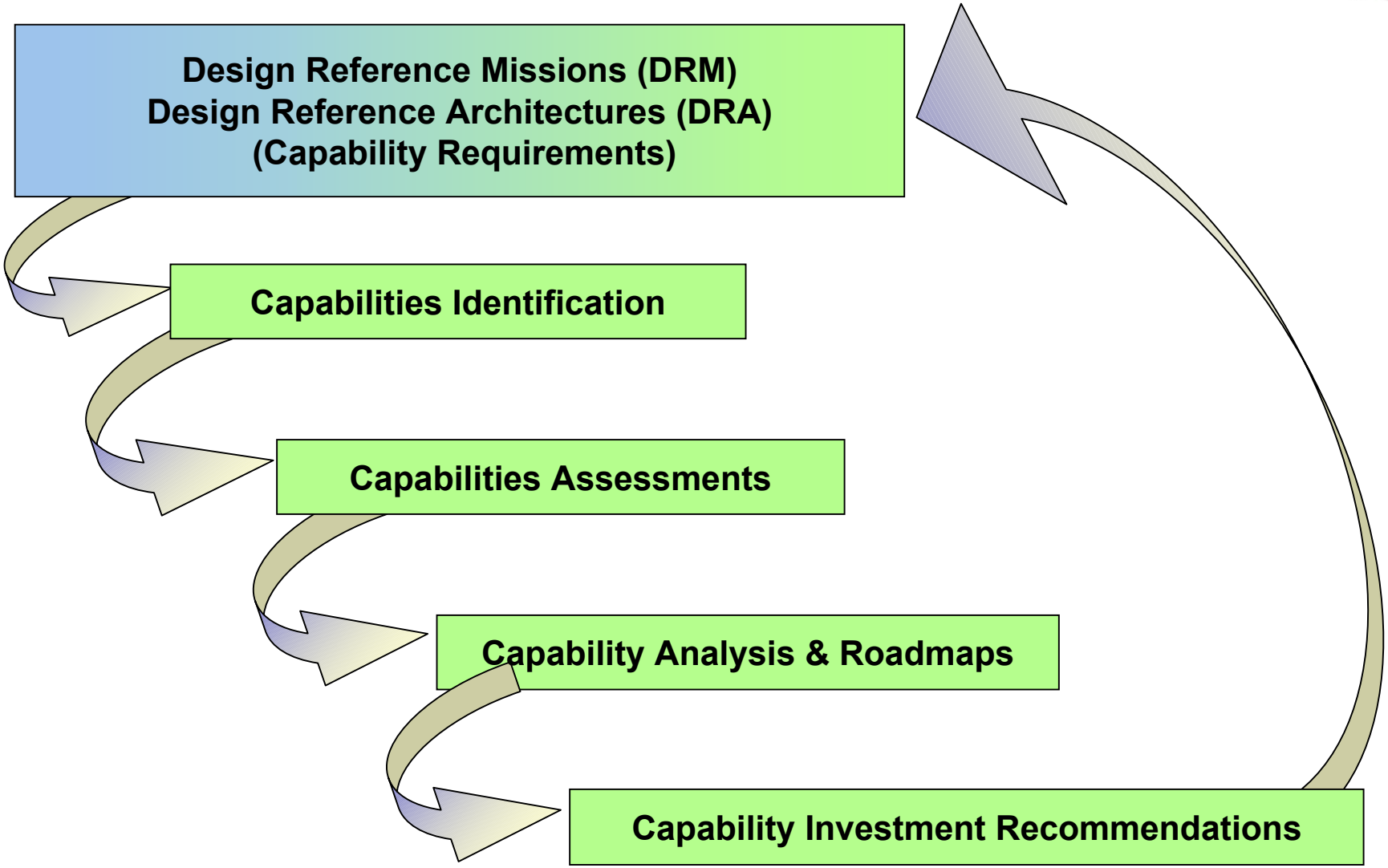
- CRAI Process
  - NASA-wide team assembled
  - Database instruments developed
  - Independent review implemented
  - Investment strategy tools incorporated
  - Multi-year, iterative process

CRAI is in Formulation.

Represents the Agency’s first structured attempt to do capability analysis based on the Exploration Vision.

Although substantial progress has been made in both the Capability and Technology areas - presented at this workshop - more work needs to be done.

Capability Analysis Process



DRMs / DRAs and Capability Identification

- Capability assessment is highly dependent on the Design Reference Missions (DRMs) & Design Reference Architectures (DRAs)
  - Initial CRAI meeting held with the Architecture team to establish deliverables, dependencies, and milestones.
  - Exploration DRM/DRA currently under development, not available for CRAI use as a reference

- FY 04 Capability heritage
  - Red/Blue Team activity surveyed past major Moon/Mars mission studies.
  - Built a matrix of capabilities vs. missions
  - Identified capability hits – if a capability was identified across a majority of the missions, in all likelihood that capability would appear in the next generation DRM/DRA.
  - Seventy capabilities identified, coalesced to 57 assessed by CRAI in FY 04

Agency baselined DRMs, DRAs, and the capability requirements/assumptions that flow from these references are critical for capability analysis and roadmapping.

Capability Assessments

- Driven by requirements and data – not technology advocate opinions
- Uniform, configuration controlled, and structured for integrated analysis from the beginning of the process
- Capability datasheets capture:
  - Capability description
  - Capability requirements from DRM/DRAs
  - Current Capability SOA
  - Mission driven SOA
  - Summary cost and schedule estimates
- Technology datasheets capture
  - Technology program traceably to Capabilities, and therefore contribution to the mission
  - Current technology SOA
  - Mission driven SOA
  - Summary cost and schedule estimates

Capability assessments based on mission requirements and detailed data - structured and formatted for strategic analysis - leads to traceable and defensible investment recommendations.

Integrated Capability Analysis and Roadmaps

- Capabilities do not stand alone – part of an integrated system and analysis process
- CRAI strategic analysis process integrates, prioritizes, assesses risk (developmental, cost,schedule), and supports a structured and defensible strategic decision-making
- The Capability and Technology datasheets are crafted to capture data for the analysis – the backbone of the processes. Requires centralized management to get data in the requisite format and uniform depth.
- Integrated Capability Roadmaps dependent on the strategic analysis process. Resultant Roadmaps would be integrated, traceable, and defensible.
- Investment recommendations are the end result and goal of the strategic analysis process

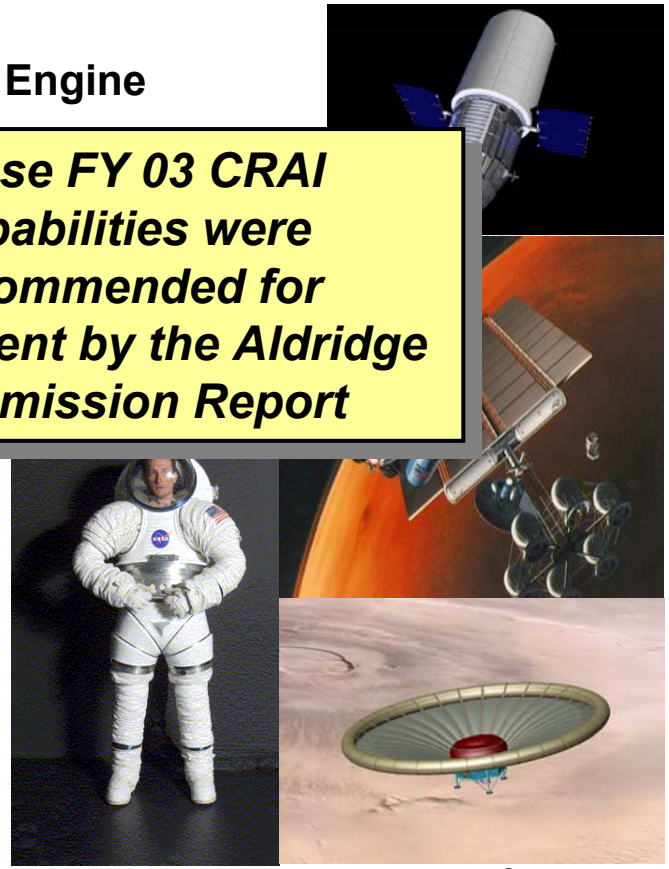
The strategic analysis process is critical to producing integrated Capability Roadmaps and investment recommendations that are traceable to Agency missions.

FY 03 Technology Assessments

The Capability Requirements Analysis and Integration (CRAI) team recommended near-term investments in the following key Exploration-enabling capabilities:

1. Technologies for an Affordable Heavy Lift Capability
2. Extremely Lightweight, Integrated Primary Multifunction Structure with Modular Interfaces
3. High Thrust, High Life Cycle, Reusable In-Space Main Engine
4. Advanced Power & Propulsion
5. Cryogenic Fluid Management
6. Large Aperture Systems
7. Formation Flying
8. High Bandwidth Communications
9. Entry, Descent and Landing
10. Closed Loop Life Support and Habitability
11. Extravehicular Activity Systems
12. Autonomous Systems and Robotics
13. Scientific Data Analysis
14. Biomedical Risk Mitigation
15. Transformational Spaceport & Range Technologies
16. Automated Rendezvous & Docking

These FY 03 CRAI capabilities were recommended for investment by the Aldridge Commission Report



FY04 Space Architect Support Plan

Objective: Answer the following questions from an Agency perspective:

- **Do the current Agency space technology development activities support the Space Architect's Integrated Architecture and have maximum cross-Enterprise benefits?**
  - **Refocused on Exploration Vision**
- **What are the capability and technology gaps that need to be addressed to enable the Space Architect's Integrated Architecture?**
  - **White Papers, Portfolio & Technology analysis**
- **What should the Agency's space capability development investment priorities be and what do their associate roadmaps look like?**
  - **Portfolio & Technology analysis**

FY04 CRAI Products

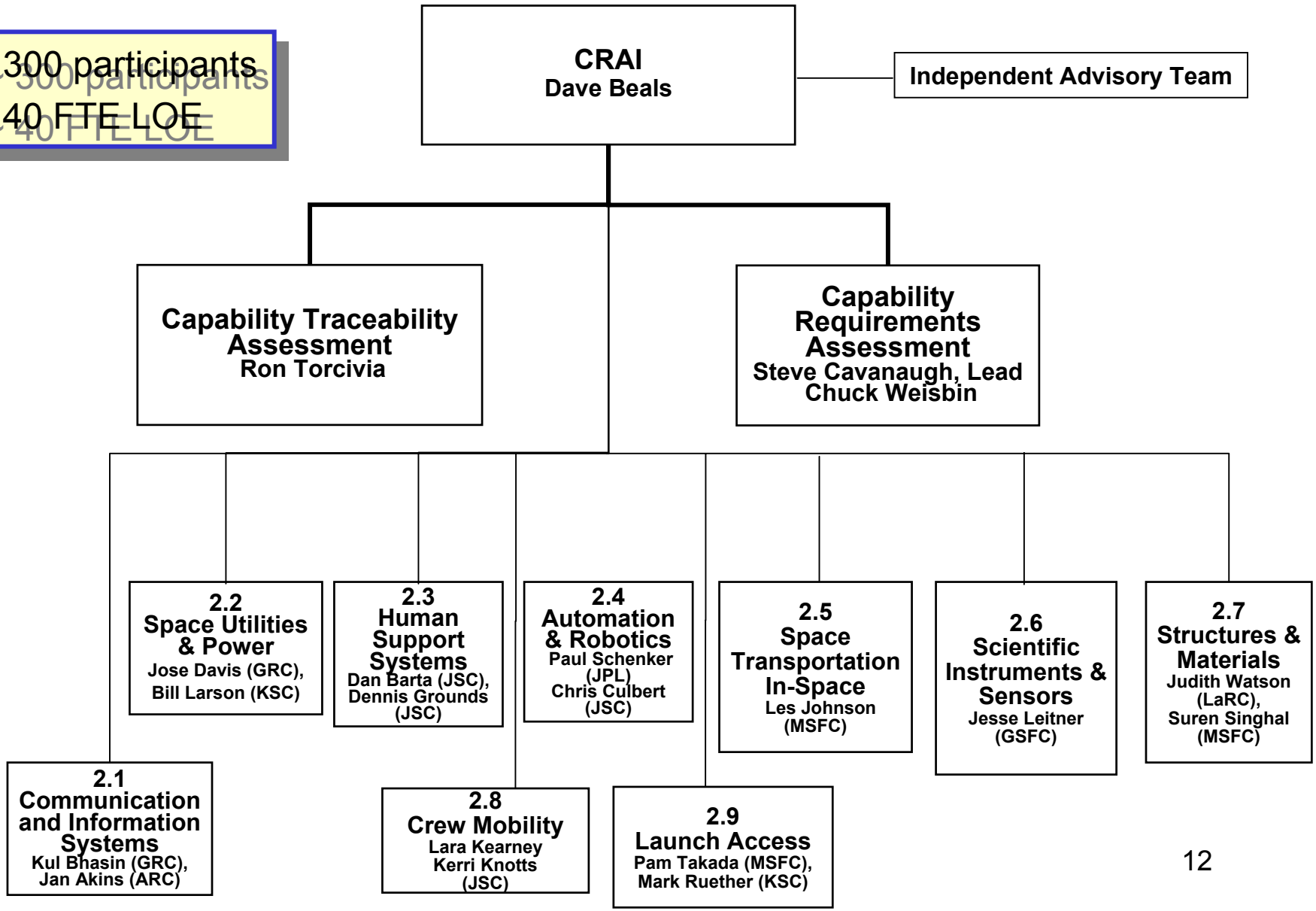
- **Agency capability and technology traceability assessment showing linkages from NASA development activities to Space Architect's space strategy**
  - **Capability datasheets**
  - **Technology datasheets**
- **Integrated Agency long-term capability investment strategy required to implement the space strategy with supporting rationale**
  - **Portfolio & Technology Analysis**
  - **Capability White papers**
  - **AR&D Independent Assessment**
- **FY05 CRAI Space Architect Support Plan**
  - **No longer required**
- **Summary Report with supporting documentation**

CRAI FY 04 Products:

57 Capabilities assessed	441 Technology datasheets	54 White Papers
Portfolio Analysis Report	Technology Analysis Report	Recommendations
	AR&D IA Report	

CRAI Organizational Structure (8/5/04)

~300 participants
~40 FTE LOE



FY 04 Capabilities

2.1 Communications, Computing, & Information Systems

- Communications
- Computing Systems
- Information Systems

2.2 Space Utilities and Power

- Power Generation
- Power regulation and Conversion
- Energy Storage
- ISRU
- Cryogenics
- Environmental Durability/Survivability

2.3 Human Support Systems

- Atmospheric Management
- Advanced Water recovery Systems
- Waste Management
- Crop Datasheets
- Human Factors
- Advanced Thermal Control Systems
- Human Support Systems
- Advanced Environmental Monitoring and Control
- Advanced Food Technology

2.4 Robotics

- Modeling and Simulation
- Robotics
- Surface Operations
- Subsurface Operations

2.5 In-space Transportation

- OMS RCS Engines
- Integrated CH4-gO2 RCS
- Integrated O2-gH2 RCS
- High Performance LH2-LOX Main Engine
- Solar Electric Power
- Nuclear Electric Power
- Nuclear Thermal Power
- Precision Entry, Descent, and Landing
- Long Term Cryogenic Storage
- Zero-g Fluid Management
- On-Orbit Cryo Storage and transfer
- Aero-Capture / Aero-Braking Entry, Descent, and Landing
- Autonomous Operations
- Aerodynamics of Non-Traditional Shapes

2.6 Scientific Instruments and Sensors

- Formation Flying
- Large Aperture Technology
- Detector and Instrument Technology

FY 04 Capabilities (continued)

2.7 Structures and Materials

- Thermal Protection
- Lightweight, Multifunctional, Integrated Primary Pressurized Structure for Crew Habitation
- Lightweight Cryogenic Propellant Tanks
- Radiators
- Novel Structural Approaches
- Radiation Protection
- Advanced Composites
- Seals and Mechanisms for Dust Control and Long Life
- Structures for On-Orbit Assembly

2.8 Crew Mobility (EVA Systems)

- Portable Life Support System
- System Integration
- Crew Surface Mobility
- Airlocks

2.9 Launch Systems

- Integrated System Health Management
- Materials and Structures
- Navigation, Guidance, and Control
- Ground Operations

FY04 Milestones

Capability Assessment & Traceability plans established: Dec 30

Kickoff Meeting: Jan 13-15

Integrated NASA Research, Discovery: March
and Exploration Model Captured

Critical Capabilities Derived from Architecture: March
– Feed into New Initiatives

Capability Requirements Meeting: Mar 30-Apr 1

Capability data sheets for critical capabilities: April 22 *(Actual: May 7)*

Draft Technology data sheets for critical capabilities less cost: May 15

Final Technology data sheets for critical capabilities with costs: June 15

Interim Critical Capability draft White Papers, Roadmaps, Budget: June 15

Capability Assessment Meeting: June 15-17 *(July 13 - 15)*

Capability Assessments Complete: July 31 (*Aug 31)*

Recommendations Integration Meeting: August 17-19 *(Sept. 14 – 16)*
- **Final White Papers, Roadmaps, Budget Runouts**

Recommendations Developed: August 31 *(Sept. 30)*

Final Deliverable to ISP: Sept 29 *(Early Oct)*

CRAI Portfolio Analysis

- Given:
  - Desired and state of the art engineering capabilities for a myriad of desired performance objectives and a finite but adjustable resource investment
- Analysis Products:
  - ***Determine the technology portfolio which will maximize the relative net performance increase in capabilities***, consistent with specified uncertainty estimates, subject to resource constraints.
  - ***Identify major technological "tall poles",*** at any given level in the hierarchical structures provided by each area: individual performance metrics, technology thrusts, technology areas, etc.
  - ***Identify major technological cost drivers*** at each level in the same hierarchy
  - ***Identify major technological uncertainties and risk*** sources at each level in the same hierarchy

Lead by Chuck Weisbin, JPL

Portfolio analysis adopted by: Code M (Investment Prioritization to maintain Shuttle Safety through ISS Assembly Complete - 25 missions in next 5 years), as well as code R (Division of Strategic Planning) and Code T (prior ECS and ECT programs)

Technology Analysis

- Independent Assessment of Technology Requirements
- Technology Gap Analysis
- Prioritization of Technology by Importance to Space Exploration Missions

Products:

- **The products of this effort provide the basis for decisions regarding the funding, timing, and scope of space exploration missions.**

Lead by Bob Lord (SAIC) and Dr. Alan Wilhite, NIA (GT)

Special Topic - Automated Rendezvous and Docking (AR&D) IA

- **Charter**

  -Assess the competing approaches to AR&D at JSC and MSFC

  -Recommend a technical approach

  - -Feasibility
  - -Risks
  - -Alternatives
  - -Cost

  -Programmatic issues added to the charter

- **Status**
  - Recommended a formulation strategy for an AR&D Program
    - Scope
    - Products and Deliverables
    - Estimated cost and schedule to formulation completion
  - Identified a need for an Agency policy debate and decision on the degree of autonomy acceptable for crewed missions.
    - Policy effects numerous other Exploration systems
  - Exploration Directorate; Project Constellation is initiating Formulation for an AR&D program. (Pete Vrotsos)

Strategy to Tactics process demonstrated

Strategic analysis by CRAI - Tactical Implementation by Constellation

Summary

- Strategic analysis and recommendations for investments are the CRAI FY 04 products.
  - Capability & Technology datasheets
    - Quantitative data
  - Capability White papers
    - Capability description/scope
    - Gap analysis
    - Roadmap to fill the gap
  - Capability strategic analysis: a structured, data-driven, and traceable method for strategic decision making.

- AR&D IA influential in the initiation of Formulation for this capability within the Exploration Mission.

CRAI Lessons Learned

- Capability requirements from Mission Concepts, DRMs/DRAs, are essential to meaningful roadmapping, strategic analysis and capability prioritization.

- Iteration and feedback between the “official” Agency mission/architecture and the capability assessment is essential.
  - Not yet in place

- To base an approach on structured, defensible analysis, data collection and the V & V of the data is critical.

- Data collection is difficult, time consuming, and requires dedicated resources – and is essential to the credibility and integrity of the product.

CRAI Lessons Learned *(continued)*

- Even limited Peer Review of the data greatly strengthens the CRAI credibility and integrity of the data – worthy of expansion.

- White papers and Roadmaps are not the final product. The integration, prioritization, and investment decisions are the important final products.

- Adjudicating between competing interests, agendas, and advocacy requires active leadership and management. A *OneNASA* approach is essential.

Managing the capabilities and analyzing them requires a highly disciplined and structured approach. Even with this, much attention is required to keep the process whole.

Open work

- Complete Formulation of the process
  - Fill in missing pieces and continue the iterative process
  - Complete development of investment analysis tools

- Exploit “capability” concept to Formulate technology programs; i.e. the implementation of *Strategy to Tactics*

- Adjust capability suite as exploration mission DRM’s emerge; establish DRM/DRA design and Capability analysis feedback loops.

CRAI
Final FY 04

Technical Datasheet &
White Paper List

2.1 Communications and Information Systems

			No. of TDS
2.1	**Communications, Computing, and Information Systems**		**133**
		Communications	113
		Computing Systems	3
		Information Systems	17
	White Papers		
		Advanced Avionics, a NASA Strategic Partnership	
		High Efficiency Computing	
		Integrated Systems Health Management; A Catalyst for Sustainable Exploration	
		Intelligent, Integrated Vehicle Management	

2.2 Space Utilities and Power

			No. of TDS
2.2	**Space Utilities and Power**		**38**
	2.2.1	Power Generation	12
	2.2.2	Power regulation and Conversion	6
	2.2.3	Energy Storage	8
	2.2.5	ISRU	6
	2.2.6	Cryogenics	5
	2.2.8	Environmental Durability/Survivability	1
	White Papers		
		Advanced Power	
		In-Situ Resource Utilization	
		Surface Cryogenics and Consumables Station	
		Integrated Cryogenic thermal Management for Lunar Surface	
		Intelligent Reliable Instrumentation (IRI)	

2.3 Human Support Systems

			No. of TDS
2.3	**Human Support Systems**		**49**
		Atmospheric Management	4
		Advanced Water recovery Systems	6
		Waste Management	7
		Crop Datasheets	7
		Human Factors	4
		Advanced Thermal Control Systems	3
		Human Support Systems	6
		Advanced Environmental Monitoring and Control	3
		Advanced Food Technology	9
	White Papers		
		Human Health Counter Measures	
		Behavioral Health and Performance	
		Autonomous Health Care	

2.4 Automation and Robotics

			No. of TDS
2.4	**Automation and Robotics**		**16**
		Modeling and Simulation	3
		Robotics	9
		Surface Operations	3
		Subsurface Operations	1

2.5 Space Transportation In-Space

			No. of TDS
2.5	**In-Space Transportation**		**45**
	2.5.1	OMS RCS Engines	4
	2.5.2	Integrated CH4-gO2 RCS	4
	2.5.3	Integrated O2-gH2 RCS	4
	2.5.4	High Performance LH2-LOX Main Engine	2
	2.5.5	Solar Electric Power	5
	2.5.6	Nuclear Electric Power	Same 5 as 2
	2.5.7	Nuclear Thermal Power	3
	2.5.8&9	Precision Entry, Descent, and Landing	8
	2.5.10	Long Term Cryogenic Storage	1
	2.5.11	Zero-g Fluid Management	1
	2.5.14	On-Orbit Cryo Storage and transfer	1
	2.5.15	Aero-Capture / Aero-Braking Entry, Descent, and Landing	5
	2.5.16	Autonomous Operations	4
	2.5.17	Aerodynamics of Non-Traditional Shapes	3
	White Papers		
		Cryogenic Oxxygen/Methane OMS/RCS Engines (.5 - 45 KN)	
		Long Term Cryogen Storage	
		Zero-g Fluid Management	
		On-Orbit Cryogenic Fluid Transfer	
		Aerocapture	
		Automated Rendezvous and Docking	
		Aerodynamics of Non-Traditional Shapes	
		Integrated Gaseous Oxygen/Methane RCS System	
		Integrated Gaseous Oxygen/Hydrogen RCS System	
		High Performance LOX-LH2 Main Propulsion	
		Solar Electric Propulsion	
		High Power Nuclear Electric Propulsion	
		Nuclear Thermal Propulsion	
		Precision Entry, Descent, and Landing	

2.6 Scientific Instruments and Sensors

			No. of TDS
2.6	**Scientific Instruments & Sensors**		**55**
		Formation Flying	49
		Large Aperture Technology	4
		Detector and Instrument Technology	2
	White Papers		
		Large Aperture Systems	
		Formation Flying	

2.7 Structures and Materials

			No. of TDS
2.7	**Structures and Materials**		**28**
	2.7.1	Thermal Protection	5
	2.7.2	Lightweight, Multifunctional, Integrated Primary Pressurized Structure for Crew Habitation	0
	2.7.3	Lightweight Cryogenic Propellant Tanks	1
	2.7.4	Radiators	4
	2.7.5	Novel Structural Approaches	5
	2.7.6	Radiation Protection	6
	2.7.7	Advanced Composites	6
	2.7.8	Seals and Mechanisms for Dust Control and Long Life	1
	2.7.9	Structures for On-Orbit Assembly	0
	White Papers		
		Mitigation of the Effects of Lunar Dust	
		Advanced Seal Development	

2.8 Crew Mobility

			No. of TDS
2.8	**Crew Mobility**		**42**
		Portable Life Support System	7
		System Integration	6
		Crew Surface Mobility	15
		Airlocks	4

2.9 Launch Access

			No. of TDS
2.9	**Launch Access**		**35**
		Integrated System Health Management	10
		Materials and Structures	8
		Navigation, Guidance, and Control	6
		Ground Operations	11